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A. R. SATULLO
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Practical Methods of Testing Condensers

PART 2

By the Engineering Department, Aerovox Corporation

THE capacity of low voltage high-capacity electrolytic condensers can conveniently be found by the voltmeter-ammeter method, mentioned in last month's Research Worker. When it is required to find the power factor or the equivalent series resistance as well as the capacitance, the system can be expanded to find these quantities in two ways. One method employs a voltmeter, ammeter and wattmeter. The diagram of connections of these three instruments, together with a variable source of supply is shown in Figure 1. The power transformer is chosen so as to deliver an alternating voltage of desired frequency within the rating of the condenser. If the condenser is of the polarized type, a d.c. power pack must be connected in series with the a.c.

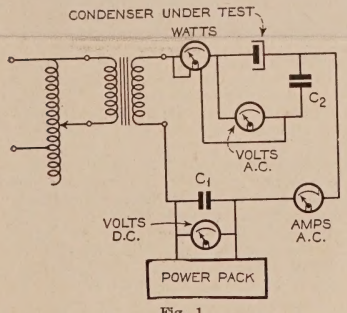

Fig. 1

The magnitude of the d.c. voltage shall then be at least as large as the peak voltage of the transformer. C_1 is to by-pass the power pack and should be as large a condenser as possible because the alternating voltage divides across C_1 and the unknown, the larger voltage appearing across the smaller condenser. C_2 should be an oil or wax paper condenser. Its size should be chosen so as to provide a reactance which is small compared to the resistance of the voltmeter. The wattmeter has to be of a special kind since the current is going to be so much out of phase with the voltage that an unusually heavy current will flow. Such "low power factor wattmeters" are available.

Readings are made on all three instruments simultaneously; the desired quantities are then given by the equations:

Capacitance

$$C_X = \frac{1{,}000{,}000}{2\pi f\sqrt{\left(\frac{E}{I}\right)^2-\left(\frac{W}{I^2}\right)^2}} \text{ MICROFARADS}$$

Equivalent series resistance

$$R_X = \frac{W}{I^2} \text{ OHMS}$$

$$\text{Power factor} = \frac{100\ W}{E\ I} \text{ percent}$$

A simplified formula for the capacity, neglecting the equivalent series resistance, is

$$C = \frac{1{,}000{,}000\ I}{2\pi f E} \text{ MICROFARADS}$$

In all the foregoing equations the units are volts, amperes, watts and cycles per second.

For the special case of 110 volt motor-starting condensers, which are tested without the d.c. power pack, the chart of Figure 2 permits the rapid determination of capacitance and power factor when the three meter readings have been made. It will also show the capacity from voltmeter and ammeter reading alone.

The use of the chart is as follows. It is assumed that all measurements are taken at 110 volts, 60 cycles. Then, reading the current, find the value of the current on the bottom scale, marked "amperes", follow the vertical line upwards until it intersects the line A or B marked "mfds" and follow the horizontal line to the right reading the capacity at the right. The capacity can also be found directly above the corresponding current on the line C-C.

To find the power factor from the wattmeter and ammeter readings, draw a horizontal line from the power scale at the left and vertical line from the ampere scale at the bottom. Read the power factor at the intersection of the two lines. The capacitance is found from the ammeter reading as before.

Example: To find the capacity when the ammeter shows 2 amperes. At 2 on the current scale, follow the vertical line upwards to its intersection "X" with the line marked "mfds. scale A", then follow the horizontal line towards the right and read the capacity on the right hand scale—48 mfds. The same can also be found at Y on the C-C scale.

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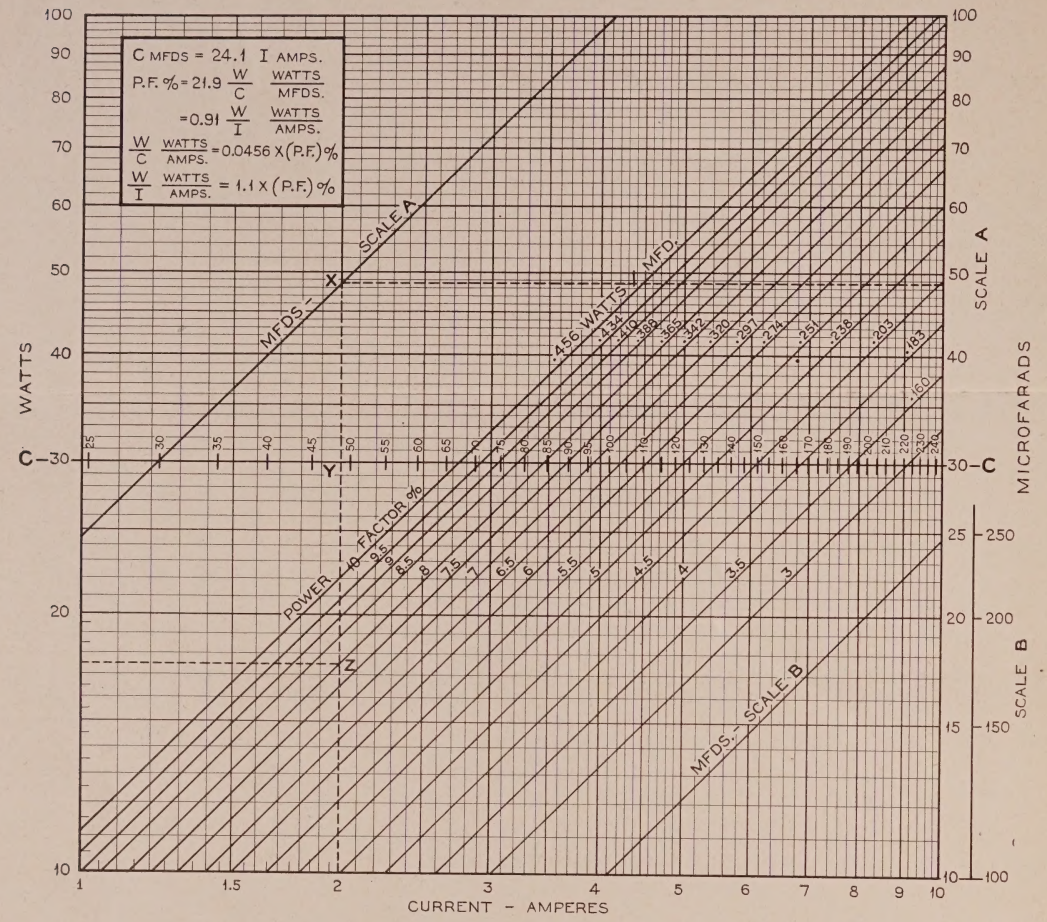


Fig. 2

To find the power factor of a condenser which draws 2 amperes and 17.5 watts from the 110 volt line. At 17.5 on the power scale draw a horizontal line. This intersects the vertical line erected at 2 on the current scale at the point Z. This point is situated on the line corresponding to 8 percent power factor.

The same problems can also be worked backwards, that is, when the capacity is given the current can be found from the chart and when the power factor and the capacity are known, both meter readings can be predicted.

Example: Required to find the current drawn by a 200 mfd. condenser from a 110 volt line. Find 200 on the capacity scale B, follow the horizontal line to the left until its intersection with the oblique line marked "mfds. scale B" follow the vertical line down and read 8.2 amperes. Note: as mentioned in Part I, the current is 41 ma. per mfd. when a condenser is connected across a 110 volt 60 cycle line.

If the same condenser had a power factor of 3.5 percent, what would be the power indicated by a wattmeter? Follow the vertical line at 8.2 amperes until it crosses the 3.5 percent power factor line, then follow the horizontal line to the left and read 32 watts. The chart can be used for any other voltage, E, if both the power and the current scale are multiplied by the factor E/110.

THREE VOLTMETER METHOD

Another measuring scheme for determining the same three quantities is similar in principle to the well known "three voltmeter method" although it does not require three voltmeter readings in this case. Basically, the method consists of measuring the impedance of the condenser by the voltmeter ammeter method, then adding a known resistance and measuring the impedance again by the same method. The three quantities, R, Z_1 and Z_2 are then related to each other as shown in the diagram of Figure 3 and the values of Rx and Xc can easily be found by ordinary geometry.

The circuit is shown in Figure 4. Here we have again a variable power supply and polarizing voltage, if needed, while R is a suitable resistance which can be shorted by the switch S. C_1 and C_2 fulfill the same function as before. The procedure consists of first closing the switch and

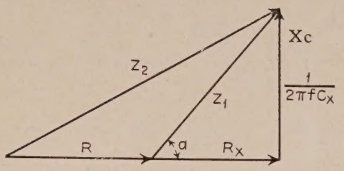


Fig. 3

measuring voltage and current, giving us E_1 and I_1. Then the switch is opened and another set of readings taken, to be known as E_2 and I_2. It is often more convenient to readjust the voltage so as to make E_1 equal to E_2.

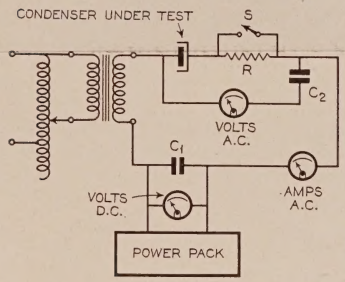


Fig. 4

The magnitude of the capacitance and equivalent series resistance are now given by the equations:

$$C_X = \frac{1{,}000{,}000}{2\pi f \sqrt{\left(\frac{E_1}{I_1}\right)^2 - R_X^2}} \text{ MICROFARADS}$$

$$R_X = \frac{\left(\frac{E_2}{I_2}\right)^2 - \left(\frac{E_1}{I_1}\right)^2 - R^2}{2R} \text{ OHMS}$$

The power factor is a function of the angle a in Figure 3, being equal to the cosine of this angle

$$PF = \cos a = \frac{100\ I_1\ Rx}{E_1} \text{ percent}$$

In all of the above equations the units are volts, amperes, ohms and cycles per second.

In order to obtain the best accuracy of measurement the value of R should be approximately equal to the value of Rx. Keeping the value of E and R constant for a series of measurements it is very simple to make a set of curves for the different values of Rx in a coordinate system where I_1 is the abscissa and I_2 the ordinate. A capacity scale can be drawn directly opposite the I_2 scale. Such curves and further information on this method are found in the Research Worker of September 1936.

More precise methods of the determination of Cx and Rx of large condensers require special bridges which will be discussed in later installments.

MEASUREMENT OF LEAKAGE

Leakage of electrolytic condensers is simply measured by means of a milliammeter in series with the condenser while it is placed across a power supply of the desired voltage. The necessary precautions have to be taken for safeguarding the instrument. It should be a multi-range instrument if possible and it should be set on its highest range or be short circuited while the condenser is charging. In addition, a limiting resistor can be placed in series with the circuit which will hold the current to a safe maximum if the condenser were shorted during the test.

The leakage to be expected is a function of the capacity. A good 8 mfd. condenser of 450 volt rating may have a leakage of 1 or 2 ma. If the condenser has not been in use for some time, the initial leakage will be very much higher than this but it will gradually come down while the condenser is being tested on a higher potential than it has been subjected to in service.

Measuring the leakage or insulation resistance of wax impregnated paper condensers requires a much more sensitive instrument since the resistance may be up to 50,000 megohms or higher, again depending on the capacity. One of the simplest and most reliable methods is to place the condenser across some 300 volts of B-battery in series with a limiting resistor of 1 megohm and a multi-range microammeter having a low range of 0-1 microampere.

Again taking the necessary precautions, the meter must be fused and set to its highest range or shorted while the condenser is charging. It is customary to allow three minutes for the charging process. Then the meter may be switched to lower and lower ranges until the leakage current can be read. The insulation resistance is then easily found by Ohm's Law.

A variation of the above method is shown in Figure 5. This circuit is probably preferred by those who do not possess a sensitive micro-ammeter. The condenser is placed in series with a high resistance of the order of 1 to 5 megohms. The leakage through the condenesr will then cause a voltage drop across this resistance and the voltage drop is measured with a vacuum-tube voltmeter.

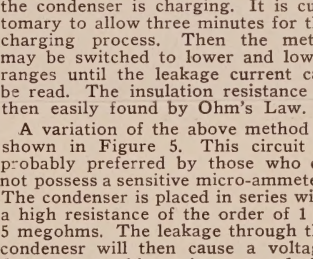


Fig. 5

In Figure 5, the condenser is shown in series with a battery (preferably 250-300 volts). First the condenser should be charged by setting the switch on a. R_2 is a limiting resistor which protects the battery in case the condenser were shorted. An indicating meter in series with R_2 can be added if desired.

When the condenser has been charged, the switch is moved to c and the voltage drop across R is read on the vacuum tube voltmeter. If this voltage drop is called e and the condenser charging battery has a voltage E, the insulation resistance is

$$\frac{E\ R}{e} \text{ megohms}$$

when R is expressed in megohms.

Changing the value of R permits the use of several ranges.

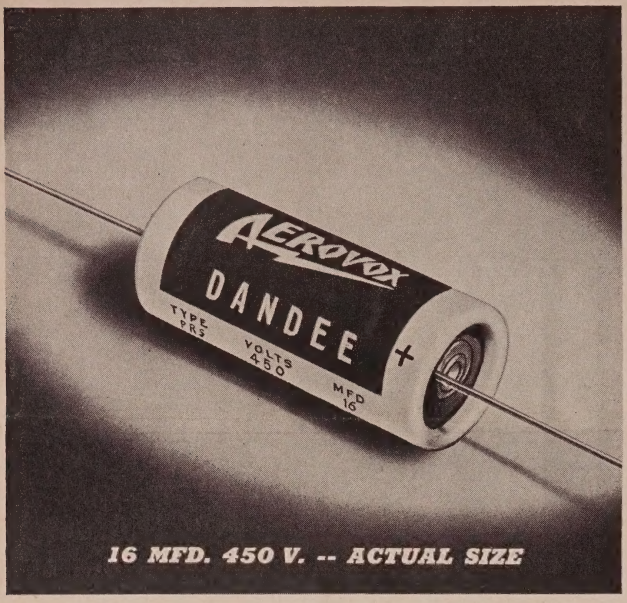
The vacuum-tube voltmeter shown can consist of a battery-operated type 30 tube, biased as an amplifier. The steady current can be bucked out with a battery or by another suitable means. The voltmeter can be calibrated on d.c. There is no reason why an a.c. operated supply could not be used for the voltmeter. A 55 or 85 tube would perhaps be best since a grid cap is desirable.

Taking the condenser charging voltage from a power pack is not recommended unless the unit is unusually well regulated. Any little variation in voltage will cause charges and discharges of the condenser which result in violent movements of the meter so the result cannot be read. See the May 1936 issue of the Research Worker for further information on this subject.

New Thordarson Transmitter Guide

Once again Thordarson comes forth with a mighty important contribution to practical "ham" literature in the form of its new No. 344-C Thordarson Transmitter Guide. This new edition contains 48 pages as against 32 for the previous edition.

Six engineers of the Thordarson organization, who are likewise active amateurs, compiled the constructional data ranging from 5 and 10 watt transmitters, beginners' and portable transmitters, all the way up to ambitious 500 and 1000 watt transmitters, together with a mass of mighty important technical data. There is data on modulation principles, calculations for Class A, B and C circuits, driving power and driver transformer ratios, overloading of modulator tubes, bias supply circuits, oscilloscope foundation unit, revised FCC regulations, and a lot more. A copy of this guide may be obtained from your local jobber handling Thordarson products, or direct from Thordarson Electric Mfg. Co., 500 W. Huron St., Chicago, Ill., for 15 cents.



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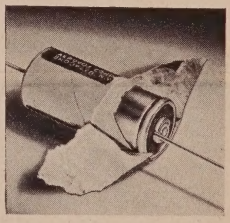
PRS 150	8	150	9/16 x 1-11/16	.45
PRS 150	12	150	11/16 x 1-11/16	.50
PRS 150	16	150	11/16 x 1-11/16	.55
PRS 150	24	150	11/16 x 2-3/16	.60
PRS 150	30	150	11/16 x 2-3/16	.65
PRS 150	40	150	13/16 x 2-3/16	.70
PRS 250	4	250	9/16 x 1-11/16	.45
PRS 250	8	250	11/16 x 1-11/16	.50
PRS 250	12	250	13/16 x 1-11/16	.65
PRS 250	16	250	13/16 x 2-3/16	.75
PRS 350	4	350	9/16 x 2-3/16	.50
PRS 350	8	350	13/16 x 1-11/16	.55
PRS 350	12	350	13/16 x 2-3/16	.70
PRS 350	16	350	13/16 x 2-3/16	.80
PRS 450	4	450	13/16 x 1-11/16	.55
PRS 450	8	450	15/16 x 1-11/16	.60
PRS 450	12	450	15/16 x 2-3/16	.75
PRS 450	16	450	1-1/16 x 2-3/16	.90

*A tolerance of plus or minus 1/32" should be considered for all sizes



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